River at Highway 50 was 968,000 ft^3/day. The simulated flow was 972,000 ft^3/day. Total simulated discharge to lake was 159,000 ft^3/day.

6.4 Calibration to Spring 2002 Conditions

Specified boundary conditions for the spring 1996 calibration included lake elevation, pumping rates, and recharge to aquifer. The measured lake elevation was specified as 6223.1 ft MSL, the pumping rates at all wells were specified equal to the average pumping rates for 3 months prior to the calibration date. Recharge to the aquifer was set equal to 0.004 ft/day, the equivalent of 17.5 in/yr.

Calibration targets included 14 groundwater elevation measurements taken in March 2002 by the South Tahoe Public Utilities District, and stream flow data from 2 gages along Trout Creek and 1 gage along Upper Truckee River.

As with the fall 1996 calibration study, the spring 2002 calibration consisted primarily of adjusting the constant head boundaries along the mountain front to match measured groundwater levels at adjacent wells. Constant head boundaries were further adjusted to simulate measured flows in Trout Creek and the Upper Truckee River. Through model calibration, a good match between measured and simulated water levels was attained. The mean difference between measured and simulated water levels was less than 1 ft. The measured flow of Trout Creek at Martin Avenue was 1,395,000 ft^3/day. The simulated flow was 1,400,000 ft^3/day. The measured flow of the Upper Truckee River at Highway 50 was 5,065,000 ft^3/day. The simulated flow was 5,050,000 ft^3/day. Total simulated discharge to lake was 318,000 ft^3/day.

7. MODEL APPLICATION

7.1 General

As illustrated by Figure 11, the lakeshore was discretized into 4 regions: Region 1 (the west), Region 2 (Tahoe Keys), Region 3 (South Lake Tahoe), and Region 4 (Stateline). The shoreline length of Region 1 is approximately 9200 ft. The shoreline length of Region 2 is approximately 6000 ft. The shoreline length of Region 3 is approximately 9700 ft. The shoreline length of Region 4 is approximately 8600 ft. The total length of the lakeshore in the model domain is approximately 33,500 ft. The model consists of 5 layers at the shoreline. This allowed for the plan- and side-view discretization of water exchange between the lake and groundwater. The model was applied under varying hydrologic conditions.

7.2 Simulation of Lake-Groundwater Interaction

As discussed in Section 6, the model was calibrated to fall 1996 and spring 2002 conditions. The lake level in fall 1996 was 6226.5 ft MSL. The lake level in spring 2002 was 6223.1. Thus, it can be inferred that the increased discharge to the lake during spring

2002 was largely the result of the lower lake level, which is not a function of seasonal fluctuations, but more a function of longer-term trends in lake elevation. Lake elevations varied from a high of 6228.1 ft MSL and a low of 6219.1 ft MSL between 1957 and 2002. The average lake elevation during this period was 6225.0 ft MSL. The fall 1996 and spring 2002 models, extrapolated to represent conditions for a full year, could be considered to represent high and low discharge values. Therefore, a reasonable, though not absolute, range of total flux rates to the lake would be between 145,000 ft^3/day and 318,000 ft^3/day.

The fall 1996 and spring 2002 models were rerun using 1996-2002 averaged pumping rates. This included the new Valhalla well at the western end of the site. Applying current average pumping rates to both models allows for an analysis of current flow conditions. Using this new pumping scenario, total simulated discharges from groundwater to the lake were 165,000 ft^3/day and 306,000 ft^3/day for "low discharge conditions" and "high discharge conditions" respectively. Normal annual discharge was estimated to be 226,000 ft^3/day (2.6 ft^3/sec), the average of these low and high discharge conditions. Figure 11 presents the distribution of water exchange between groundwater and the lake in plan view. Figures 12 and 13 present the vertical delineation of simulated "high discharge conditions" and "low discharge conditions" representations of water exchange between groundwater and the lake. The normal average year is based upon taking the average of annually extrapolated spring 2002 (high discharge) conditions and fall 1996 (low discharge) conditions.

7.3 Analysis of Hydrologic Effects of Groundwater Pumping

A precursory analysis was performed to quantify the effects of pumping on lake-groundwater interaction and stream flows. The "low discharge conditions" model was used for this analysis. Pumping rates were adjusted to the average withdrawal rates for the period 1996 to 2002.

An initial simulation was run where all pumping wells were removed from the model, and a comparison was made between the model results with pumping and without pumping. Total discharge from groundwater to the lake increased from 145,000 ft^3/day (with pumping) to 403,000 ft^3/day (without pumping). Discharge from groundwater to streams increased from 359,000 ft^3/day (with pumping) to 529,000 ft^3/day (without pumping). Discharge from streams to groundwater decreased from 64,000 ft^3/day to 600 ft^3/day. Outflow from Trout Creek increased from 2,000,000 ft^3/day to 2,113,000 ft^3/day. Outflow from the Upper Truckee River increased from 1,020,000 ft^3/day to 1,141,000 ft^3/day. The total discharge increase to the lake via surface water (234,000 ft^3/day) or groundwater (258,000 ft^3/day) was 492,000 ft^3/day (5.7 cfs). The total simulated pumping in the study area was 844,000 ft^3/day (9.8 cfs). Thus, approximately 60% of groundwater withdrawn from wells directly impacts surface waters by reducing stream flow or reducing lake volume.

The simulated effect of pumping from the Al Tahoe and Paloma wells was also investigated. Average 1996-2002 pumping rates at these two wells were

362,000 ft^3/day and 145,000 ft^3/day respectively. A simulation was run where these two wells were removed from the model, while all other pumping wells remained. A comparison of model results with and without the Al Tahoe and Paloma wells was made. Simulated flows from groundwater to the lake increased from 145,000 ft^3/day to 314,000 ft^3/day, an increase of 169,000 ft^3/day. Simulated flows from the lake to groundwater decreased from 195,000 ft^3/day to 8,000 ft^3/day, a decrease of 187,000 ft^3/day. Thus, simulated results indicate about 37% of pumped water from the Al Tahoe and Paloma wells has the lake as its source. The simulated effect of the Al Tahoe and Paloma pumping wells on stream flows was less pronounced. With the Al Tahoe and Paloma wells turned off, simulated outflows at the lake from Trout Creek increased by 60,000 ft^3/day to 2,060,000 ft^3/day; simulated outflows at the lake from the Upper Truckee River increased by 40,000 ft^3/day to 1,060,000 ft^3/day.

8. SENSITIVITY ANALYSIS

8.1 General

An "average conditions" model was developed by employing averaged boundary condition values to the current calibrated model. Pumping rates at all wells were averaged for the period of 1996-2002 and input into the model. The average lake elevation for the period of 1957-2002 (6225 ft MSL) was input into the model. Averaged 1996-2002 stream flows (Section 2.3) were simulated by the model. Constant head values used in the spring 2002 calibration study were used. Recharge was set to an estimated average annual value of 0.003 ft/day (13.1 in/yr). Simulated discharge to the lake was 240,000 ft^3/day. The "average conditions" model was used for the analysis of the influence of model parameters and conceptualizations on simulated results.

Sensitivity analysis is used to measure the uncertainty in the calibrated model caused by uncertainty in estimates of aquifer parameters and boundary conditions. During sensitivity analysis, parameters are systematically changed, one at a time, within a predefined plausible range factor. The accompanying change in model results are then analyzed as a measure of the sensitivity of the model to that particular parameter. Factors of 0.5 and 2.0 were selected as a plausible range of aquifer parameters and boundary conditions.

8.2 Analysis of Hydrologic Parameters

The "average conditions" model (Section 8.1) was used to estimate the influence of various model parameters on groundwater discharge to the lake. Hydrologic parameters were varied by factors of 2.0 and 0.5. These parameters include horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv), recharge to the water table, and lakebed conductance (COND). Results of this study are presented as Table 2.